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Sustainable performance-oriented production practices in the Indian iron and steel industry: An empirical investigation

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ABSTRACT

Capital-intensive industries consume fossil fuels for mass production with little concern for nature's assimilative capacity, which results in an accumulation of greenhouse gases (GHGs). Pollution abatement systems based on market-induced correctives and multi-national agreements works as ex-post remedial measures and have limited effectiveness in the reduction of GHGs. In this paper, we formulate the sustainable-structure-conduct-performance (S-SCP) paradigm as an ex-ante remedial measure by mimicking the structure-conduct-performance (SCP) paradigm to reduce the GHGs. By using a dynamic panel data, the workability of the S-SCP paradigm was tested on CO_2 emissions for selected major Indian iron and steel industries (IISI). Our findings show that the green relative index was positively significant in respect of green value added (GREVA). However, green R&D and barriers to entry and exit were negatively significant in respect of GREVA. Overall, the S-SCP paradigm's test in ISII suggests that the incorporation of social cost into the firm's structure and conduct will achieve sustainable performance-oriented production practices that reduce CO_2 emissions. We propose general suggestions on industrial parks for green technology innovation, management responsibility mechanisms, environmental impact assessment notifications and an Indian sustainable development commission.

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1. Introduction

Humanity has long exploited natural resources to satisfy its wants and needs within the limits of natural carrying and assimilative capacities. To that end, it has established property rights, invented technologies and adopted production practices in order to maximize profits, all of which has ultimately led to the exploitation of resources beyond capacities (Meadows et al., 1992). Thus, behavioural changes by humans have not only contributed to society's gross domestic product (GDP) but also to the extinction of natural resources and growing pollution.

Since the 1930s, the world population, GDP and CO_2 emissions have grown 3.4, 18 and 8 times, respectively (De Long et al., 2006; World Bank, 2017; Marland et al., 2008). Substantial changes have also taken place in terms of property rights, the information and communication technologies, the reduction of trade barriers, the free flow of investment and labour, the improvement to transport technology and the granting of state subsidies, all of which have notably reduced the transaction costs of global trade. However, objectionable production practices mark the current state of economic growth and development *vis-à-vis* pollution.[2] The intergovernmental panel on climate change (IPCC, 2013) has observed across the world the impact of climate change on physical, biological, human and managed systems. A number of scholars (Goldstein et al., 2011; Ortiz and Markandya, 2009) have estimated the costs and benefits of climate change. Stern (2006) argues that if

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[2] The fact that the Keeling curve indicates that CO_2 emissions of 318 ppm in 1958 reached 410.58 by March 2018 (Scripps Institution of Oceanography, 2018) is a public bad. Among other things, of all the greenhouse gases (GHGs) attributable to human activity, CO_2 has the highest positive radiative forcing (about 1.6). The Intergovernmental Panel on Climate Change (IPCC, 2013) has stated that the increase in CO_2 emissions raised the Earth's average surface temperature by 0.85 °C between 1880 and 2012. Nature takes about 1000 years to increase CO_2 concentrations by 30 ppm but the latest 30 ppm increase has taken a mere 17 years (IPCC, 2007).

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we fail to act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year — a figure that rises to 20% when a wider range of risks and effects are taken into account.

Although the market-induced correctives, *viz.* economic instruments, market creation, and liability system, as well as multinational agreements such as the Kyoto Protocol, have been designed to mitigate CO_2 emissions, they essentially work as *ex-post* remedial measures to reduce the emissions, i.e. they provide for remedial measures after harm occurred. As such, they have serious limitations to control emissions. In view of such limitations to reducing emissions, we attempt to formulate the sustainable-structure-conduct-performance (S-SCP) model as an *ex-ante* remedial measure by mimicking the SCP paradigm. The S-SCP model will provide incentives to producers to adopt sustainable performance-oriented production practices at the firm level with the aim of reducing CO_2 emissions. In the paper, we test the workability of this sustainable-SCP (S-SCP) model for selected major Indian iron and steel industries (IISI).

The S-C-P paradigm generates information on workable competition among the firms in a given market. State formulates antitrust regulations based on the information and makes the firm no choice except to comply with the paradigm or to pay penalties for anti-competitive practices. Authors mimic the paradigm and formulate the S-SCP to generate information on the social cost of the market share for a given firm (Sustainable- Structure) and provide incentives to producers to adopt sustainable oriented production practices (Sustainable Conduct) to reduce CO_2 emission in order to produce green products and services (Sustainable-Performance).

1.1. The rationale for the sustainable-structure-conduct-performance (S-SCP) model

The rationale for the formulation of the S-SCP model is based on three facts. First, the SCP paradigm in what refers a reduction of dominant firms' abuses (Mason, 1939; 1949). Second, the producers' sovereignty and the concept of revised sequence (Galbraith, 1970). Third, the inefficacy of *ex-post* measures —the market induced correctives and the multi-national agreements —in reducing GHGs (Third Conference of the Parties-United Nations Framework on Climate Change Convention). The S-SCP paradigm works as complementarity to *ex-post* measures in order to reduce CO_2 emissions. According to Porritt (2018), “if the individual companies get involved in the sustainable development goals with a clear commitment to delivering ‘equitable share value’, then people might feel inclined to trust business more as genuine co-creators of sustainable wealth”.

1.1.1. The SCP paradigm

The SCP paradigm is a model in the field of Industrial Organization first published by Edward Chamberlin (1933), and later developed by Edward Mason (1939) and Joe S. Bain (1951). It establishes “a stable and causal relation between the structure of industry, firm conduct and market performance exists” (Mason, 1939; 1949). Hence, altering the industry's structure in a specific way will enhance the market performance and, in turn, promote allocative efficiency. During the 1940s, the Harvard school of thought interpreted the SCP paradigm as a unidirectional approach; namely, the structure of the industry influences the firms' performance through the firms' conduct. It also states that the profits obtained in a market are higher the higher is the concentration degree of the market. Then, the traditional SCP paradigm focuses on the reduction of the market concentration and the promotion of competition among the firms. Later, during the 1960s, the Chicago school proposed the “efficiency structure hypothesis”, which stressed the importance not on the size of the firm, but on the market power of the dominant firm. Thus, the role of legislation should not be to prohibit the dominant firms as such, but to monitor their abuse activities, which impede competition. Hence, the Chicago approach viewed the efficiency of a firm as a dominant variable over the market structure in determining the production and pricing policy of the firm in an industry (Clarke, 1988).

The SCP paradigm enables regulators to identify firms indulging in anti-competitive practices and abuses and determine the impact of such practices to enact anti-trust laws so that firms are penalized when they fail to comply. The paradigm thus promotes competitive practices among the firms and this, in turn, may help to protect the interests of consumers (Kambhampati, 1996). It is worth noting that the SCP paradigm is not designed to protect the interests of the society as a whole, since it does not take into account the social cost of environmental damage. This ultimately motivated us to mimic such paradigm in the domain of environmental goods and services and develop the S-SCP paradigm.

1.1.2. Producers sovereignty

The Galbraith's notion of revised sequence motivated us to explore the idea of producers playing a proactive role (representative responsibility) in the reduction of their emissions. Sustainable performance-oriented production practices would create and control a market for green goods and services (with reduced emissions) in which consumers would have a little role except that of consuming. Various modern firms such as Apple, Google, Amazon or Facebook seem to work in line with the Galbraith's viewpoint of consumers who do not always know what they want from the producers of goods and services. Hence, the producers should predict the future consumer demand, innovate and develop the products, and market them accordingly. The success lies in the fact that these companies have been able to develop flagship products, which are better, cheaper and greener than their predecessors, hence redefining the benchmarks of the products over the time.

1.1.3. Ex-post remedial measures

Market induced correctives, *viz.* subsidies, cap-and-trade, Coase's theorem and liability system, were designed to reduce CO_2 emissions. However, pervasive subsidies provide incentives to existing firms to promote their operations and impede to potential competitors to enter the industry. According to the World Energy Outlook 1999 (IEA, 2013), by providing incentives to lock-in the existing infrastructure that increases global warming, subsidies lead to distortion of markets and create barriers to invest in cleaner energy. Similarly, the allocation of permits by way of grandfathering will create the risk of hoarding, and may result in the erection of entry barriers. Moreover, an auction of permits will incur high information and legal costs. In the case of Pigouvian taxes (Baumol, 1972), the cost of monitoring various emission sources may either raise the collection cost or lead to few sources going untaxed. As proposed by (Buchanan, 1969; Cropper and Oates, 1992, among others), “the monopolistic power of emitters in their output markets, especially the energy sector, reduces the welfare gain from the GHGs emissions taxes. Indeed, emitters that have market power will respond to the emissions taxes by adjusting product prices to maximize their profits”. High positive transaction costs between North and South countries will limit the application of Coase theorem (Coase, 1960) to reduce emissions. Finally, the liability system's causational link, law's delay, under compensation and appeals provisions unable to deter the polluters on social costs.

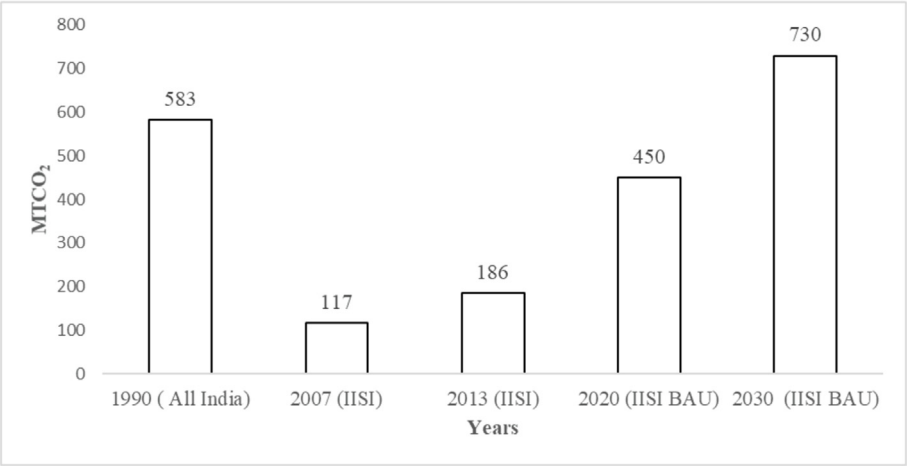

Fig. 1. Indian economy and IISI CO_2 emissions and business-as-usual (BAU) scenarios.
Source: IEA (2013, p. 52); Indian Network for Climate Change Assessment (2010, p. 43); and projections for 2013, 2020 and 2030: authors' calculations for the IISI.

On the other hand, multi-national agreements, *viz.* the Kyoto Protocol, have set binding targets[3] in the first commitment period, 2008–2012 (UNFCCC, 1998). However, the natural-resource-rich South countries and the technological-rich North countries each have concerns about economic growth and development *vis-a-vis* the environment. Hence, GHGs reduction measures according to Kyoto Protocol Annex B were achieved a little on the set binding gases targets during the first commitment period. Similarly, in 2005, the second commitment period (2013–2020) was launched in Montreal (Canada), extending the Kyoto Protocol beyond 2012 (COP11–UNFCCC); accordingly, countries committed to cut their GHGs emissions by at least 18% below 1990 levels in the second period. However, the world economy has added another 20 gigatonnes, since the second commitment period. Hence, climate change under business as usual scenario necessitates incentives structure in-built *ex-ante* measures to reduce CO_2 emissions.

Thus, the above arguments led us to mimic the SCP paradigm and develop the S-SCP model, as an *ex-ante* remedial measure, to try to reduce CO_2 emissions at the firm level. The S-SCP model will generate information on green performance indicators that will provide incentives to producers to take sustainable performance-oriented production practices to enhance the green profile of their firms within the industry. Furthermore, policymakers can use the generated information to reward the greener firms and incentivize non-green firms to adopt the S-SCP paradigm. Firms would also benefit society through the development of climate-proof forward and backward linkages (Terpstra and Mc Gray, 2013). We presume that the S-SCP model will work as complementarity to the *ex-post* remedial measures, and we test it in the Indian iron and steel industry (IISI).

1.2. Energy trends in India

At present, India accounts for about 17.74% of the world population and 2.4% of the world's landmass. In 2015, it exploited about 4%, 2% and 8% of the world's resources of oil, gas and coal reserves, respectively (British Petroleum, 2015). Annual Indian GDP (in terms of purchasing power parity) grew from 23.19 billion USD in 1950 to 2.6 trillion USD in 2017 (World Bank, 2017). India's GDP accounted for 4.19% of the world's GDP (World Trade Organization, 2017), while its CO_2 emissions contributed approximately 6.6% to the world's CO_2 emissions (British Petroleum, 2015).

1.2.1. Energy intensive industries

Energy intensive industries (i.e. aluminium, cement, fertilizers, petrochemicals, chemicals, glass, textiles, iron and steel, and pulp and paper) contributed about 41% of the Indian economy's net value added in 2012, but consumed 66% of total fuel (in monetary terms) used in the country, according to the Annual Survey of Industries (Ministry of Statistics and Programme Implementation, Government of India, 2016). The IISI is the highest fuel consumer among energy-intensive industries, accounting for 20% of the economy's fuel consumption while contributing 14% of the economy's net value added (Annual Survey of Industries, Government of India, 2012).

1.2.2. The indian iron and steel industry

According to our estimates, while aggregated CO_2 emissions for four energy-intensive industries (aluminium, cement, iron and steel, and pulp and paper) for 2012 were 211 $MTCO_2$ (Capitaline database,[4] 2017; IPCC, 1996), the major iron and steel producers alone accounted for 116 $MTCO_2$ (i.e. roughly 55%) of those direct emissions. Energy consumption by IISI is around 25% of the total energy consumption of the Indian manufacturing sector (IEA, 2012), while its raw material consumption in 2013 was about 73.8% that of the metal and mining industry as a whole (Krishnan et al., 2013). Our estimates indicate that IISI will emit 440 $MTCO_2$ by 2020 and 730 $MTCO_2$ by 2030 under a business-as-usual scenario[5] (see Fig. 1).

The CO_2 intensity of primary steelmaking in India works out at 2.7 $MTCO_2$ per MT of crude steel; excluding the Essar Group's gas-based steel plant, this figure is more than 3 $MTCO_2$ (Bhushan et al., 2012). Both figures are far above the worldwide standard of 1.4 $MTCO_2$ per tonne of crude steel (Ministry of Steel, Government of

[3] For 37 industrialized countries and the EU to reduce greenhouse gases by an average of 5% against 1990 levels.

[4] The Capitaline database is the most reliable Indian corporate database: https://www.capitaline.com).

[5] Carbon intensity for Indian crude steel in 2007 was 2.25 $MTCO_2$ per MT (Indian Network for Climate Change Assessment, 2010). Projected steel production for 2020 and 2030 is 200 MT and 325 MT, respectively (Ministry of Steel, Government of India).

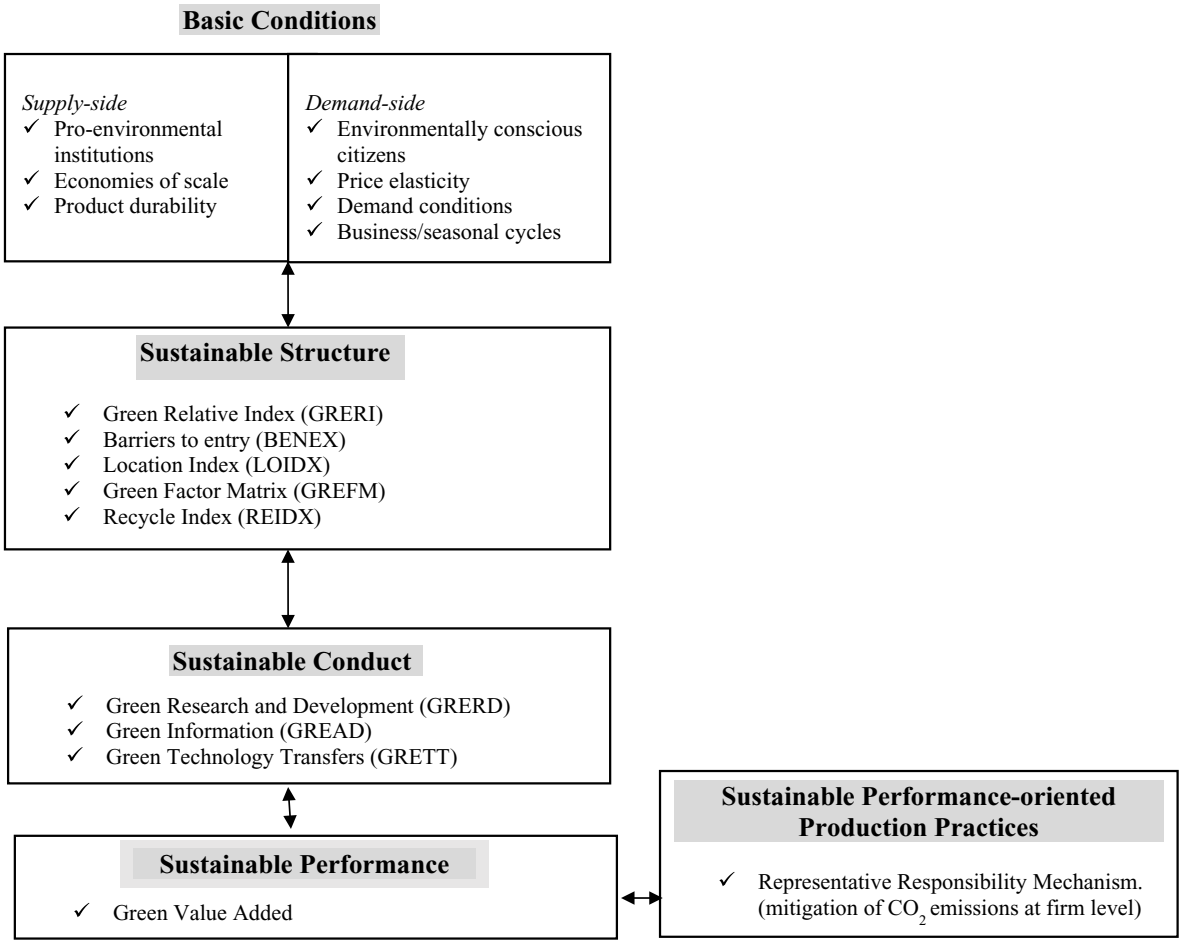

Fig. 2. Two-way S-SCP paradigm components.
Source: Adapted from Scherer and Ross (1990, p.5).

India, 2012a). In addition, actual investment in R&D by IISI is in the range of 0.15%–0.3% of total firms' turnover, compared to the 1%–2% invested by foreign firms (Ministry of Steel, Government of India, 2012b).

The Indian Ministry of Steel has identified 12 firms as the major Indian iron and steel producers, accounting for 7.5% of the total number of such firms (160) and for around 68.6%, 60.3% and 81.2% of market share (sales), raw material consumption and energy costs, respectively (Capitaline database). A complete set of data was not available for four of the 12 firms (Jindal Saw Ltd, Jindal Stainless Ltd, Jindal Steel and Power Ltd. and Visvesvaraya Iron & Steel Ltd). Thus, we exclude these firms from our study, leaving eight firms (Steel Authority of India Ltd., Bhushan Steel Ltd., Bhushan Power & Steel Ltd., Essar Steel Ltd., JSW Steel Ltd., Tata Steel Ltd., Uttam Galva Ltd. and Rashtriya Ispat Nigam Ltd.). Jointly, they accounted, in 2012, for 59.3%, 52.1%, and 69.7% of market share (sales), raw material consumption and energy costs, respectively, of the corresponding figures for the entire sector composed of 160 firms (Capitaline database). The period chosen for the study was 2003–2012 for eight major firms manufacture multiple products and sell their intermediate product (pig iron) to each other.

Our findings show that the green relative index (GRERI) was positively significant in respect of green value added. However, green R&D and barriers to entry and exit were negatively significant in respect of green value added. Beyond this, the inferences of S-SCP model, as an *ex-ante* system, may provide information about the determinants of sustainable performance-oriented production practices, which highlights their advantages; namely, green profits to shareholders, supply of green products to consumers, better quality of life to population, protection for environment, and cost saving to the society. The S-SCP model also highlights the representative responsibility on reduction of CO_2 emissions and, in turn, enhances the goodwill of the firm.

The remainder of the paper is organised as follows. Section 2 examines the S-SCP paradigm. Section 3 deals with the data and methodology used in this research. In Section 4 we provide the main results. Section 5 contains some implications and the direction for future work.

2. The sustainable structure-conduct-performance paradigm

The S-SCP model introduces an environmental conservation component into the SCP model for workable sustainable (or green) competition.[6] We formulate the paradigm as a dynamic relationship between S–S, S–C and S–P, referring to the structure, conduct and performance components, respectively, as depicted in Fig. 2.

In what follows, we provide a detailed explanation of the S-SCP paradigm.

[6] The firm tries to reduce its efforts on pollution within the natural assimilative capacity within the competitive market situation.

Table 1
Sustainable-Structure (S–S) variables.

Variable	Definition
Green relative index (GRERI) (Source: Authors)	GRERI = Market share of ith firm/CO_2 emission share of ith firm, where Market share = Real net sales of ith firm/Real net sales of iron and steel industry.
Barriers to entry/exit (BENEX) (Source: Bragg, 2010)	BENEX = Gross block of ith firm/real net sales of ith firm, where Gross block is defined as the total value of all assets that a company owns before depreciation.
Green factor matrix (GREFM) (Source: Authors)	$GREFM = \frac{\text{Expenditure on renewable inputs}}{\text{Expenditure on total inputs}}$ Expenditure on renewable inputs by ith firm/Expenditure on total inputs by ith firm
Location index (LOIDX) (Source: Santos et al., 2008)	LOIDX = (Net value added by ith firm/Iron and steel industry net value added)/(Net added value of iron and steel industry of states where firm ith plants are located/Net added value of state where firm ith plants are located)
Recycling Index (REIDX) (Source: Authors)	REIDX = Value of recycling material (production, by-products and scraps) of ith firm/Value of the firm's total inputs of ith firm

Note: GRERI and BENEX are inverse related to a firm's S–P.
GREFM and REIDX are positive related to a firm's S–P.

2.1. Basic conditions

The basic conditions for the S-SCP paradigm in a given time period are determined by various factors that influenced the green market structure in previous years and, therefore, can be assumed to be exogenous at least in the short run. In the S-SCP model, these conditions influence the rate at which firms shift their goal from maximizing profits to the maximization of green profits. For instance, environmentally consciousness citizens and pro-environmental institutions in the EU have developed workable sustainable competition that is in line with sustainable performance-oriented production practices (EUROPA, 2017).

2.2. Sustainable-structure

Sustainable-Structure (S–S) are both exogenous and endogenous factors that industry will possess and develop over the time and in turn facilitate in shifting from conventional production practices to sustainable performance-oriented production practices. The S–S variables are defined in Table 1.

Only a value higher than 1.25 for LOIDX indicates regional specialization (Santos et al., 2008). The prevalence of a cluster in an industry will have positive implications for a firm's S–P.

2.3. Sustainable-Conduct

Sustainable-Conduct (S–C) incorporates all strategies of the firm aimed at reducing emissions and enhancing R&D and marketing activities. The S–C variables are defined in Table 2.

GRERD covers strategies such as investments in green product manufacturing, eco-processes and eco-solutions. Developing countries like India do not have the first best environmental policies that signal the maintenance of mandatory accounts for GRERD to firms. Since estimates of output-oriented variables were difficult, we used input-oriented R&D data under the assumption that green R&D and generic R&D would be strongly correlated (Jaffe and Palmer, 1997). Likewise, GRETT is the outcome of the interaction of dummy variables with TTPS. We assume that firms that voluntarily participate in recognized programmes such as the Climate Action Recognition Programme of the World Steel Association (WSA, 2019) (a) will adapt and buy green technologies, and (b) will have a state-of-the-art environmental management system.

2.4. Sustainable-Performance

Sustainable-Performance (S–P) of a firm is determined on the basis of the conservation of resources and the reduction of CO_2 emissions, as well as the generation of green profits to shareholders. The proxy chosen for S–P is the green value addition (GREVA), which reveals how much additional real net value a firm can add if it releases one more unit of CO_2 emission. GREVA can be formulated as the ratio of real net value addition per unit of CO_2 emission of a given firm and, enhancing GREVA, will yield double dividends — green profits and reduced CO_2 emissions — with implications not only for that firm, but also for investors and consumers, that is, for society as a whole.

2.5. Specification of the sustainable SCP paradigm

Until the mid-20th century, the SCP literature assumed a unidirectional approach, namely from market structure to market conduct and, eventually, to market performance. However, advances in econometrics techniques have led to the development of better and more sophisticated models. Accordingly, we used a

Table 2
Sustainable-Conduct (S–C) variables.

Variable	Definition
Green R&D (GRERD) (Source: Authors)	GRERD = Expenditure on green R&D of ith firm/Net sales of ith firm.
Green technology transfer (GRETT) (Source: Authors)	$GRETT_{it} = D_{it}$ x $TTPS_{it}$, where subscript *i* represents firms and subscript *t* represents years, D_{it} is a dummy variable for participation in a CO_2 emissions reduction programme (National or International) and acquiring ISO 9000 (Quality management, efficiency, effectiveness and auditing), and $TTPS_{it}$ denotes royalty payments per net sales.
Green advertisement (GREAD) (Source: Authors)	GREAD = Expenditure on green advertisement of ith firm/Real net sales of ith firm

Note: The three indexes have a reciprocal relationship with the firm's S–P. We assume that firms acquiring ISO 9000 and simultaneously participating in CO_2 emissions reduction programme will purchase green technology. Royalty payment per net sales is taken as a proxy for technology transfer.

dynamic panel data model (Arellano and Bond, 1991) to specify the relationship between S–S, S–C and S–P at the firm level (Baltagi, 2005), which can be formulated as follows:

$$y_{it} = \alpha y_{i,t-1} + x'_{it}\beta + u_{it},\ i = 1,\ldots, N;\ t = 1,\ldots, T, \quad (1)$$

where y_{it} denotes S–P at the firm level in period t, x'_{it} is the vector of S–S and the S–C variables at the firm level in period t, and α is a scalar (i denotes the corresponding firm, and t represents time). We assume that u_{it} follows a one-way error component model as:

$$u_{it} = \alpha_i + \nu_{it}, \quad (2)$$

where α_i is a time-invariant unobservable, $\alpha_i \sim$ iid $(0, \sigma^2_\alpha)$ and ν_{it} are time-varying unobservable, and where $\nu_{it} \sim$ iid $(0, \sigma^2_\nu)$ are independent of each other and among themselves. The models take care of the inbuilt dependency between S–S, S–C and S–P and their lag values. Thus:

$$GREVA_{it} = \beta_i + \beta_2 GREVA_{i,t-1} + \beta_3 GRERI_{it} + \beta_4 BENEX_{it} + \beta_5 GREFM_{it} + \beta_6 LOIDX_{it} + \beta_7 REIDX_{it} + \beta_8 GRERD_{it} + \beta_9 GRETT_{it} + \beta_{10} GREAD_{it} + \mu_{it}, \quad (3)$$

where β_i is a time-invariant unobservable and μ_{it} is a time-varying unobservable.

3. Data and methodology

The empirical analysis is conducted on firm-level data for the 10-year period 2003–2012[7] for the eight major firms in the IISI. Data were obtained from the Capitaline database,[8] with gaps in the data filled by the Prowess database (Centre for Monitoring Indian Economy Pvt Ltd.) and primary survey.[9] Ready-made data on firm-level CO_2 emissions were not available. While doing the primary survey, we observed that the firms are multi-products in nature and sell the intermediate product (pig iron) to each other. The pig iron production generates around 80% of the CO_2 emissions of the entire steel making process. Since the time series data on intra-sale of pig iron within the industry was not maintained, mere multiplication of each firm's steel production with average CO_2 intensity of primary steelmaking in India with i.e. 2.7 T CO_2 per MT of crude steel would have led to bias results. Hence, we first obtained the number of units of fuels consumed from the Capitaline database and, then, generated the firm-level CO_2 emissions data using the standard CO_2 conversion factor for hydrocarbons — as published by the United States Environmental Protection Agency (USEPA, 2014) — and electricity consumption data for Indian power grids — as published by the Central Pollution Board of India (CPCB, 2003). Finally, we adjust financial data against the respective price indices for inflation. To guide the reader, we summarize in Table 3 the Steel Authority of India (SAIL) calculations for CO_2 emissions.

We used a similar procedure for calculations regarding the remaining seven firms. To calculate the S–S variables GREVA (Table 4), GREMS (Table 5) and BENEX (Table 6), additional firm-level data on real net value added, net sales and gross block were obtained from the Capitaline database[10].

Table 4 reveals that over the years Tata Steel and Uttam Galva have maintained a higher value of GREVA in the year 2012, whereas SAIL has the lowest value. This may be due to the fact that SAIL is one of the major producers of pig iron (Intermediate Product) in the ISII which has low value addition per MT of CO_2 emissions than the finished steel..

Firms' GRERI value grater than 1 indicates that it has relatively higher market share *vis- a- vis*., its contribution to CO_2 emissions within the industry. Table 5 shows that Essar Steel, Tata Steel and Uttam Galva have the highest GRERI values and thus exhibit S–P characteristics. However, Bhushan Power and Steel, SAIL and Rashtriya Ispat Nigam present the lowest values of GRERI.

According to Table 6, both Tata Steel and Uttam Galva have acquired over the years the lowest values for BENEX, while Bhushan Power and Steel Ltd. has attained the highest values.

To calculate the S–S variable LOIDX (see Table 7), State-specific industry level and State level net value-added data (ASI, 2013) were obtained from the Indian annual survey of industries (ASI, 2003–2012). Data on the location of plants for each major firm were obtained from the firms' websites.

Table 7 informs that no firm besides JSW Steel have any location specialization.

To calculate the S–C variable GRERD (see Table 8), firm-level data on R&D were obtained from Capitaline database and, if necessary, from the Prowess database. In addition, to fill gaps in R&D data, primary data were obtained from Indian ministries (the Ministry of Steel and the Ministry of the Environment and Forests), from the Centre for Science and Environment NGO and directly from the departments of selected firms. No data were available for three firms (Bhushan Power & Steel Ltd., Bhushan Steel Ltd. and Uttam Galva Steel Ltd.).

Table 8 reveals that overall firms low on GRERD. Tata Steel has maintained the highest value of GRERD which is an average of about 0.20%; this is, however, 5 times less than the global average R&D in the steel industry. R&D value for Bhushan Power & Steel, Bhushan Steel and Uttam Galva was not available and hence were imputed using Amelia II.[11]

To calculate the S-C variable GRETT (see Table 9), data on technology transfer payments were obtained from the Capitaline and Prowess databases. Information on ISO-9000 (International Organization for Standards) for each of the major firms was obtained from the firms' websites. Lastly, information on participation in green projects was obtained from World Steel Association database (WSA, 2014).

Table 9 shows that the GRETT has performed poorly for all firms in ISII.

REIDX and GREAD were excluded from the model due to the non-availability of data for these variables. The data that are used for the empirical study and the respective source are summarized in Table 10.

After generating the variables, we have proceeded with unit root diagnostic test; namely, the Levin, Lin and Chu test (Baltagi, 2005). This is presented in Table 11 below.

The results obtained suggest that all variables except LOIDX and GRETT were stationary at level, although both these variables were found to be stationary at first difference.

In sum, the empirical model can be expressed as:

$$GREVA_{it} = \delta_i + \delta_1 GREVA_{i,\,t-1} + \delta_2 GRERI_{it} + \delta_3 BENEX_{it} + \delta_4 D.LOIDX_{it} + \delta_5 GRERD_{it} + \delta_6 D.GRETT_{it} + \varepsilon_{it}, \quad (4)$$

[7] After 2012, the Government relaxed the compliance on mandatory sharing production data of firms. Hence, the study is restricted to the 2003–2012 period.

[8] Capitaline and Prowess (CMIE) are digital corporate database of Indian companies.

[9] Interaction with the personnel of Ministry of Steel, Ministry of Environment and Forests, Centre for Science and Environment (CSE) and telephonic conversation with concerned Department of the firms has helped to fill the gaps on R&D data.

[10] 1 Crore = 10 Million.

[11] Amelia II is a software used to impute missing values (Honaker et al., 2012).

Table 3
SAIL CO_2 emission calculations.

Energy Type	Quantity	Units	Conversion Factor	$MTCO_2$	Total $MTCO_2$
Year – 2007					
Coke	601,000	Tonnes	3.02	1,815,020	
Coking Coal	13,550,000	Tonnes	2.44	33,062,000	
Electricity Own Generation (Steam Turbine)	948,000,000	Kilo Watt/Hour	0.00047	445,560	
Electricity Purchased	6,291,000,000	Kilo Watt/Hour	0.00089	5,598,990	
Fuel Oil (Used in Boilers & Furnaces)	51,000	Kilo Litres	2.94	149,940	
Non-Coking Coal	956,000	Tonnes	1.82	1,739,920	**42,811,430**
Year – 2008					
Coke	639,000	Tonnes	3.02	1,929,780	
Coking Coal	13,950,000	Tonnes	2.44	34,038,000	
Electricity Own Generation (Steam Turbine)	895,000,000	Kilo Watt/Hour	0.00047	420,650	
Energy Type	**Quantity**	**Units**	**Conversion Factor**	**$MTCO_2$**	**Total $MTCO_2$**
Electricity Purchased	6,483,000,000	Kilo Watt/Hour	0.00089	3,047,010	
Fuel Oil (Used in Boilers & Furnaces)	65,000	Kilo Litres	2.94	58	
Non-Coking Coal	976,000	Tonnes	1.82	2,869,440	**42,304,938**
Year – 2009					
Coke	248,000	Tonnes	3.02	748,960	
Coal	13,837,735	Tonnes	1.82	25,184,678	
Coking Coal	733,000	Metric Tonnes	2.44	1,788,520	
Electricity Own Generation (Steam Turbine)	902,000,000	Kilo Watt/Hour	0.00047	423,940	
Electricity Purchased	6,507,000,000	Kilo Watt/Hour	0.00089	5,791,230	
Fuel Oil (Used in Boilers & Furnaces)	50,000	Kilo Litres	2.94	147,000	
Non-Coking Coal	985,000	Metric Tonnes	1.82	1,792,700	**35,128,068**
Year – 2010					
Coke	790,000	Tonnes	3.02	2,385,800	
Coking Coal	13,600,000	Metric Tonnes	2.44	33,184,000	
Electricity Own Generation (Steam Turbine)	797,000,000	Kilo Watt/Hour	0.00047	374,590	
Electricity Purchased	6,631,000,000	Kilo Watt/Hour	0.00089	5,901,590	
Fuel Oil (Used in Boilers & Furnaces)	37,000	Kilo Litres	2.94	108,780	
Non-Coking Coal	13,840,000	Tonnes	1.82	25,188,800	**67,143,560**
Year – 2011					
Coal	13,940,000	Tonnes	1.82	25,370,800	
Coke	226,000	Tonnes	3.02	682,520	
Coking Coal	13,940,000	Tonnes	2.67	37,219,800	
Electricity	6,777,000,000	Kilo Watt/Hour	0.00089	6,031,530	
Electricity Own Generation (Steam Turbine)	724,000,000	Kilo Watt/Hour	0.00047	340,280	
Fuel Oil (Used in Boilers & Furnaces)	36,000	Kilo Litres	2.94	105,840	
Energy Type	**Quantity**	**Units**	**Conversion Factor**	**$MTCO_2$**	**Total $MTCO_2$**
Non-Coking Coal	700,000	Tonnes	2.44	1,708,000	**71,458,770**
Non-Coking Coal	700,000	Tonnes	2.44	1,708,000	**71,458,770**
Year – 2012					
Coke	708,000	Tonnes	3.02	2,138,160	
Coking Coal	13,940,000	Tonnes	2.44	34,013,600	
Electricity Own Generation (Steam Turbine)	619,000,000	Kilo Watt/Hour	0.00047	290,930	
Electricity Purchased	6,946,000,000	Kilo Watt/Hour	0.00089	6,181,940	
Fuel Oil (Used in Boilers & Furnaces)	57,000	Kilo Litres	2.94	167,580	
Non-Coking Coal	688,000	Tonnes	1.82	1,252,160	**44,044,370**

Source: Capitaline database (2012), Prowess database (2012), USEPA (2014), CPCB (2003), and authors' calculations.

Table 4
Sustainable-performance: GREVA.

Net real value added (in Rs Crore)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Bhushan Power & Steel Ltd	133.84	107.36	157.72	305.18	340.57	549.69	555.21	570.96	818.60	1122.49
Bhushan Steel Ltd	122.08	236.57	317.71	169.80	466.95	551.05	774.45	1151.34	1525.57	1890.92
Essar Steel Ltd	309.01	661.31	2095.69	1399.48	2153.92	1681.68	1877.29	847.37	1429.94	572.75
JSW Steel Ltd	525.80	828.86	2042.66	1509.35	2204.35	2538.28	1980.44	2737.07	2991.38	3030.27
Steel Authority of India Ltd	993.97	3345.80	10,273.35	5790.23	7753.20	8782.67	5993.61	6049.91	4907.01	3868.53
Tata Steel Ltd	3502.80	4306.23	7017.12	6853.60	7383.81	8515.10	9011.50	8896.03	10,507.53	10,283.19
Uttam Galva Steels Ltd	161.60	178.20	320.58	241.92	330.20	402.60	407.43	426.01	440.32	366.33
Rashtriya Ispat Nigam Ltd	738.67	1823.21	2724.59	1827.88	1950.69	2770.21	2251.02	633.23	1367.39	1065.22
CO_2 emissions (MT)	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Bhushan Power & Steel Ltd	219,060	500,857	313,993	426,509	1,489,699	2,359,471	3,323,613	3,914,059	5,103,553	7,113,689
Bhushan Steel Ltd	114,742	143,131	212,082	195,791	646,577	1,632,718	2,073,777	2,765,349	5,776,027	7,113,689
Essar Steel	1,178,763	2,181,741	2,980,542	1,224,679	3,765,809	4,309,970	3,955,656	3,869,389	4,917,735	4,244,177
JSW Steel Ltd	4,874,347	7,688,493	6,491,720	7,250,829	8,355,080	10,444,110	12,724,450	17,723,969	16,611,679	21,358,127
SAIL	37,970,410	44,615,640	44,479,840	49,713,590	42,811,430	42,304,938	35,877,028	67,143,560	71,458,770	44,044,370
Tata	11,958,566	14,701,103	10,659,058	12,424,627	10,830,002	12,095,021	17,531,138	16,184,143	17,896,968	18,500,669
Uttam Galva	210,442	206,134	121,405	116,328	129,399	160,232	200,563	228,694	202,234	207,002
Rashtriya Ispat Nigam	14,014,516	13,435,274	12,224,928	12,044,861	12,796,098	11,881,078	13,929,751	14,282,689	14,282,651	14,101,524
GREVA (Thousand per MT)	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Bhushan Power & Steel Ltd	6.1098	2.1434	5.0230	7.1554	2.2861	2.3297	1.6705	1.4587	1.6040	1.5779
Bhushan Steel Ltd	10.6398	16.5280	14.9805	8.6723	7.2219	3.3750	3.7345	4.1635	2.6412	2.6581
Essar Steel	2.6215	3.0311	7.0312	11.4273	5.7197	3.9018	4.7458	2.1899	2.9077	1.3495
JSW Steel Ltd	1.0781	1.0781	3.1466	2.0816	2.6383	2.4303	1.5564	1.5443	1.8008	1.4188
SAIL	0.2618	0.7499	2.3097	1.1647	1.8110	2.0760	1.6706	0.9010	0.6867	0.8783
Tata	2.9292	2.9292	6.5832	5.5161	6.8179	7.0402	5.1403	5.4968	5.8711	5.5583
Uttam Galva	7.6789	8.6448	26.4058	20.7967	25.5179	25.1258	20.3142	18.6278	21.7730	17.6970
Rashtriya Ispat Nigam	0.5271	1.3570	2.2287	1.5176	1.5244	2.3316	1.6160	0.4434	0.9574	0.7554

Source: Capitaline database (2012) and Authors' calculations.

Table 5
Sustainable-structure: GRERI.

Sales market share (in Rs Crore)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Bhushan Power & Steel Ltd	0.0295	0.0300	0.0300	0.0293	0.0312	0.0335	0.0371	0.0331	0.0340	0.0396
Bhushan Steel Ltd	0.0277	0.0300	0.0400	0.0378	0.0433	0.0404	0.0419	0.0470	0.0513	0.0587
Essar Steel	0.0398	0.0700	0.0900	0.0865	0.0925	0.1036	0.0987	0.0896	0.0903	0.0956
JSW Steel Ltd	0.0802	0.0700	0.0900	0.0859	0.0963	0.1098	0.1180	0.1531	0.1715	0.1890
SAIL	0.4342	0.4500	0.4200	0.4128	0.4091	0.3998	0.3787	0.3454	0.3224	0.2777
Tata	0.2553	0.2200	0.2100	0.2164	0.2048	0.1929	0.2086	0.2105	0.2159	0.2303
Uttam Galva	0.0192	0.0200	0.0300	0.0240	0.0278	0.0286	0.0351	0.0368	0.0361	0.0298
Rashtriya Ispat Nigam	0.1141	0.1100	0.1100	0.1073	0.0951	0.0915	0.0818	0.0846	0.0786	0.0793
CO_2 emissions share	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Bhushan Power & Steel Ltd	0.0031	0.0060	0.0041	0.0051	0.0184	0.0277	0.0371	0.0310	0.0375	0.0610
Bhushan Steel Ltd	0.0016	0.0017	0.0027	0.0023	0.0080	0.0192	0.0231	0.0219	0.0424	0.0610
Essar Steel	0.0167	0.0261	0.0385	0.0147	0.0466	0.0506	0.0441	0.0307	0.0361	0.0364
JSW Steel Ltd	0.0691	0.0921	0.0838	0.0869	0.1034	0.1226	0.1420	0.1405	0.1219	0.1830
SAIL	0.5383	0.5345	0.5741	0.5961	0.5297	0.4966	0.4003	0.5324	0.5245	0.3775
Tata	0.1695	0.1761	0.1376	0.1490	0.1340	0.1420	0.1956	0.1283	0.1314	0.1586
Uttam Galva	0.0030	0.0025	0.0016	0.0014	0.0016	0.0019	0.0022	0.0018	0.0015	0.0018
Rashtriya Ispat Nigam	0.1987	0.1610	0.1578	0.1444	0.1583	0.1395	0.1554	0.1133	0.1048	0.1209
GRERI	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Bhushan Power & Steel Ltd	9.4926	4.9998	7.4031	5.7338	1.6935	1.2094	1.0017	1.0660	0.9071	0.6500
Bhushan Steel Ltd	17.0311	17.4957	14.6139	16.0966	5.4126	2.1069	1.8122	2.1432	1.2095	0.9634
Essar Steel	2.3807	2.6782	2.3397	5.8908	1.9852	2.0467	2.2370	2.9199	2.5025	2.6275
JSW Steel Ltd	1.1601	0.7600	1.0742	0.9879	0.9318	0.8955	0.8309	1.0891	1.4064	1.0323
SAIL	0.8067	0.8419	0.7316	0.6924	0.7723	0.8051	0.9459	0.6487	0.6146	0.7358
Tata	1.5062	1.2492	1.5265	1.4528	1.5281	1.3587	1.0666	1.6403	1.6437	1.4524
Uttam Galva	6.4480	8.0988	19.1467	17.1743	17.3425	15.1998	15.6621	20.2759	24.3027	16.7961
Rashtriya Ispat Nigam	0.5743	0.6834	0.6972	0.7431	0.6007	0.6559	0.5263	0.7471	0.7500	0.6561

Source: Capitaline database (2012) and Authors' calculations.

where D.LOIDX and D.GRETT are first difference variables, δ_i is a time-invariant unobservable, ε_{it} is a time-varying unobservable, $\varepsilon_{it} \sim$ iid $(0, \sigma^2_{\epsilon})$, *i* denotes each individual firm, and *t* represents time.

Finally, from the specification of the model given in (4), we formulate the null hypothesis to be tested and the alternative hypothesis respectively as:

H0. There is no relation between the S–P of industry, the S–C of the firm and the S–P of the market, i.e. any change in S–P or S–C or both in any way will not influence change in S–P and *vice versa*.

H1. There does exists a relation between the S–P of the industry, the S–C of the firm and the S–P of the market. Hence, altering the

Table 6
Sustainable-structure: BENEX.

Gross block (in Rs Crore)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Bhushan Power & Steel Ltd	582	862	1651	3117	1918	3716	6711	7356	9439	14,632
Bhushan Steel Ltd	890	1338	1658	1796	2694	2927	3282	3686	14,424	18,203
Essar Steel	6648	6802	6940	10,448	13,554	14,689	15,368	16,329	18,188	29,349
JSW Steel Ltd	5823	6227	7520	8368	10,513	13,952	16,897	21,796	27,407	35,091
SAIL	27,535	27,684	28,043	29,360	29,913	30,923	32,852	35,396	38,236	41,728
Tata	11,800	12,506	13,179	15,407	16,029	16,480	20,057	22,306	22,846	23,486
Uttam Galva	606	640	683	974	1122	1710	2267	2466	2534	3741
Rashtriya Ispat Nigam	8731	8710	8763	8832	8876	8901	8972	9474	9795	10,394
Net real sales (in Rs Crore)	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Bhushan Power & Steel Ltd	1308	1417	1963	2322	3013	3853	4779	4205	5020	7282
Bhushan Steel Ltd	1229	1733	2829	2993	4179	4645	5395	5974	7576	10,793
Essar Steel	1765	4025	6533	6850	8928	11,911	12,704	11,388	13,346	17,561
JSW Steel Ltd	3556	3556	6713	6802	9297	12,629	15,179	19,457	25,335	34,721
SAIL	19,262	24,137	32,024	32,687	39,482	45,985	48,722	43,904	47,629	51,036
Tata	11,327	11,921	15,871	17,140	19,763	22,190	26,844	26,758	31,902	42,317
Uttam Galva	853	1221	2156	1897	2680	3288	4510	4674	5330	5475
Rashtriya Ispat Nigam	5061	6175	8188	8499	9179	10,522	10,525	10,756	11,616	14,570
BENEX	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Bhushan Power & Steel Ltd	0.445	0.609	0.841	1.342	0.637	0.965	1.404	1.749	1.880	2.009
Bhushan Steel Ltd	0.724	0.772	0.586	0.600	0.645	0.630	0.608	0.617	1.904	1.687
Essar Steel	3.767	1.690	1.062	1.525	1.518	1.233	1.210	1.434	1.363	1.671
JSW Steel Ltd	1.638	1.751	1.120	1.230	1.131	1.105	1.113	1.120	1.082	1.011
SAIL	1.429	1.147	0.876	0.898	0.758	0.672	0.674	0.806	0.803	0.818
Tata	1.042	1.049	0.830	0.899	0.811	0.743	0.747	0.834	0.716	0.555
Uttam Galva	0.711	0.524	0.317	0.513	0.419	0.520	0.503	0.528	0.475	0.683
Rashtriya Ispat Nigam	1.725	1.411	1.070	1.039	0.967	0.846	0.852	0.881	0.843	0.713

Source: Capitaline database (2012) and Authors' calculations.

Table 7
Sustainable-structure: LOIDX.

Firm value added/Industry value added										
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Bhushan Power & Steel Ltd	0.0544	0.0093	0.0063	0.0169	0.0151	0.0213	0.0243	0.0268	0.0341	0.0506
Bhushan Steel Ltd	0.0496	0.0206	0.0127	0.0094	0.0207	0.0214	0.0339	0.0540	0.0636	0.0852
Essar Steel	0.1257	0.0576	0.0840	0.0773	0.0954	0.0652	0.0822	0.0398	0.0596	0.0258
JSW Steel Ltd	0.0503	0.0722	0.0819	0.0834	0.0976	0.0984	0.0867	0.1284	0.1247	0.1365
SAIL	0.4042	0.2913	0.4118	0.3200	0.3433	0.3405	0.2623	0.2839	0.2046	0.1743
Tata	0.6014	0.3749	0.2813	0.3787	0.3270	0.3302	0.3944	0.4174	0.4380	0.4632
Uttam Galva	0.0657	0.0155	0.0128	0.0134	0.0146	0.0156	0.0178	0.0200	0.0184	0.0165
Rashtriya Ispat Nigam	0.3004	0.1587	0.1092	0.1010	0.0864	0.1074	0.0985	0.0297	0.0570	0.0480
State iron and steel value added where ith **firm has plant(s)/State total value added where i**th **firm has plant(s)**										
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Bhushan Power & Steel Ltd	0.2967	0.3721	0.4852	0.4348	0.5290	0.5540	0.5165	0.4308	0.3695	0.4799
Bhushan Steel Ltd	0.0828	0.1126	0.1593	0.1038	0.1466	0.3006	0.1357	0.1093	0.1178	0.1620
Essar Steel	0.1103	0.1487	0.2023	0.1256	0.1832	0.2988	0.1555	0.1840	0.1367	0.1916
JSW Steel Ltd	0.0449	0.0644	0.0874	0.0744	0.1127	0.1672	0.0694	0.0741	0.0729	0.0993
SAIL	0.3364	0.3542	0.4466	0.3814	0.3925	0.4551	0.4106	0.2904	0.3068	0.3711
Tata	0.7868	0.7923	0.7852	0.8120	0.8084	0.8152	0.7627	0.6119	0.7475	0.7491
Uttam Galva	0.0299	0.0615	0.0871	0.0409	0.0886	0.4752	0.0500	0.0650	0.0610	0.1480
Rashtriya Ispat Nigam	0.1297	0.1984	0.2095	0.1510	0.1669	0.1843	0.1237	0.1188	0.1023	0.1392
LOIDX	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Bhushan Power & Steel Ltd	0.1834	0.0251	0.0130	0.0388	0.0285	0.0385	0.0470	0.0622	0.0924	0.1054
Bhushan Steel Ltd	0.5999	0.1828	0.0799	0.0904	0.1411	0.0711	0.2498	0.4942	0.5397	0.5258
Essar Steel	1.1395	0.3872	0.4153	0.6158	0.5206	0.2182	0.5283	0.2161	0.4360	0.1346
JSW Steel Ltd	1.1199	1.1199	0.9371	1.1216	0.8661	0.5886	1.2485	1.7336	1.7100	1.3751
SAIL	1.2015	0.8223	0.9220	0.8388	0.8747	0.7482	0.6388	0.9777	0.6668	0.4696
Tata	0.4731	0.4731	0.3582	0.4664	0.4045	0.4050	0.5170	0.6821	0.5860	0.6183
Uttam Galva	2.2012	0.2524	0.1475	0.3269	0.1650	0.0329	0.3567	0.3074	0.3008	0.1115
Rashtriya Ispat Nigam	2.3158	0.8000	0.5212	0.6687	0.5176	0.5828	0.7966	0.2500	0.5572	0.3447

Source: Capitaline database (2012), firms' websites, Indian Annual Survey of Industry (2012) and Authors' calculations.

Table 8
Sustainable-conduct: GRERD.

R&D per net sales	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Bhushan Power & Steel Ltd	0.2350[e]	0.2344 [e]	0.2235 [e]	0.1838 [e]	0.2115 [e]	0.1672 [e]	0.1443 [e]	0.1272 [e]	0.0245	0.1279 [e]
Bhushan Steel Ltd	0.2419 [e]	0.1996 [e]	0.1842 [e]	0.2367 [e]	0.1833 [e]	0.1599 [e]	0.1460 [e]	0.1153 [e]	0.0300	0.1129 [e]
Essar Steel Ltd	0.0200	0.0300	0.0300	0.0450	0.1100	0.1200	0.1200	0.1700	0.1900	0.2100
JSW Steel Ltd	0.0700	0.0750	0.1095	0.0940	0.0700	0.0600	0.0400	0.0600	0.0700	0.0600
Steel Authority of India Ltd	0.2900	0.3000	0.1900	0.1900	0.2000	0.2200	0.2400	0.2400	0.2800	0.2700
Tata Steel Ltd	0.1700	0.2000	0.2100	0.2100	0.2400	0.2100	0.2000	0.2100	0.2300	0.1600
Uttam Galva Steels Ltd	0.1168 [e]	0.2774 [e]	0.1313 [e]	0.2840 [e]	0.1399 [e]	0.1053 [e]	0.1358 [e]	0.1682	0.2024	0.2024
Rashtriya Ispat Nigam Ltd	0.0900	0.1100	0.1100	0.1200	0.1300	0.1700	0.1600	0.1200	0.1600	0.1500

Note: Superscript e denotes imputed values using software package Amelia II.
Source: Capitaline database (2012), Prowess database (2012), primary data and authors' calculations.

Table 9
Sustainable conduct: GRETT.

Royalties per sales	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Bhushan Power & Steel Ltd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bhushan Steel Ltd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Essar Steel	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
JSW Steel Ltd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SAIL	0.0021	0.0017	0.0012	0.0016	0.0013	0.0013	0.0012	0.0059	0.0122	0.0167
Tata	0.0109	0.0114	0.0095	0.0099	0.0089	0.0077	0.0085	0.0103	0.0193	0.0216
Uttam Galva	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rashtriya Ispat Nigam	0.0004	0.0008	0.0007	0.0006	0.0004	0.0011	0.0021	0.0029	0.0021	0.0033
Participation in WSA Climate Action Programme and ISO-9000 acquired [a]	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**1**	**1**
GRETT	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Bhushan Power & Steel Ltd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bhushan Steel Ltd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Essar Steel	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
JSW Steel Ltd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SAIL	0.0000	0.0000	0.0000	0.0000	0.0013	0.0013	0.0012	0.0059	0.0122	0.0167
Tata	0.0000	0.0000	0.0000	0.0000	0.0089	0.0077	0.0085	0.0103	0.0193	0.0216
Uttam Galva	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rashtriya Ispat Nigam	0.0000	0.0000	0.0000	0.0000	0.0004	0.0011	0.0021	0.0029	0.0021	0.0033

Source: Capitaline database (2012), Prowess database (2012), firms' websites, WSA (2019) and authors' calculations.
[a] SAIL, TATA and Rashtriya Ispat Nigam became members from 2007.

Table 10
Snapshot of data and its sources.

Variables	Data Source	Nature of data
CO_2 emissions conversion factor for hydrocarbons	The United States Environmental Protection Agency	Secondary Data
Electricity consumption data for Indian power grids	Central Pollution Board of India, Government of India	Secondary data
Energy Consumption (in Quantity)	Capitaline database	Secondary data
Net Real Value added	Capitaline database	Secondary data
Sales	Capitaline database	Secondary data
Gross Block	Capitaline database	Secondary data
State-specific industry level value added	Annual Survey of Industries, Ministry of Statistics and Programme Implementation, Government of India	Secondary data
State level total net value added	Annual Survey of Industries, Ministry of Statistics and Programme Implementation, Government of India	Secondary data
Research and Development	• Capitaline database, • Prowess database, Centre for Monitoring Indian Economy Pvt. Ltd, and • Personal interviews	Secondary and Primary data
Participation in World Steel Association- Climate Action Programme	World Steel Association	Secondary data
ISO 9000	Firms 'own websites	Secondary data

Source: Author's compilation.

S–P or S–C or both in a specific way will enhance the S–P and *vice versa*.

4. Results and discussion

Although our panel data analysis was imbalanced due to a lack of data on GRERD for three companies (Bhushan Steel Ltd., Bhushan Power & Steel Ltd. and Uttam Galva Ltd.), this issue was addressed by imputing the missing values using the Amelia II –R package (Honaker et al., 2012).

We used a two-step estimator with a maximum of two lags. The diagnostic test, namely the Sargan's test for overidentifying restrictions (Sargan, 1958), confirmed that both the specification of the model and the instruments employed are valid. On the other hand, the Arellano-Bond test for zero-autocorrelation for first-

Table 11
Levin-Lin-Chu unit root test.

Variables	Adjusted t	Panel Included	Time Included
GREVA	−5.563***	Yes	No
GRERI	−2.549***	Yes	No
GRERD	−9.477***	Yes	Yes
LOIDX	−1.280	Yes	Yes
LOIDX (1)	−10.027***	Yes	Yes
BENEX	−4.124	No	No
GRETT	3.376	No	No
GRETT (1)	−1.667**	No	No
GRENW	−3.682***	Yes	No

Note: Double asterisk ** and triple asterisk *** denote significance at 5% and 1%, respectively.
Source: Authors' calculations.

Table 12
Sustainable-structure and sustainable-conduct in the IISI.

Variable category		Arellano-Bond model (robust)
Intercept		32.667***
		(2.36)
L1.GREVA		0.241
		(1.47)
Sustainable Structure	GRERI	1.431***
		(0.413)
	LOIDX (1)	−0.749
		(−0.57)
	BENEX	−12.406**
		(−2.03)
Sustainable Conduct	GRERD	−130.185**
		(−2.29)
	GRETT (1)	1002.959
		(0.93)
Sargan Test		0.142
Arellano-Bond test for Zero Autocorrelation Order 2		−0.659
Note: Single asterisk *, double asterisk ** and triple asterisk *** denote significance at 10%, 5% and 1%, respectively.		
Values in brackets are calculated z values.		
Instruments for differenced equation		
GMM-type: L (2/3).GREVA		
Standard: D.GRERI D.GRERD D2.GRETT D.BENEX D2.LOIDX		
Instruments for level equation		
Standard: Intercept		

Source: Authors' calculations.

differenced errors (Arellano and Bond, 1991) indicated that there were no problems of autocorrelation. Finally, to address the bias arising from inbuilt heteroskedasticity in the generalized method of moments, the results were recalculated using robust standard errors (Table 12).[12]

The inferences drawn were as follows. First, the model indicated that the independent variable GRERI was positively significant at the 1% level with respect to GREVA, that is, the dependent variable S–P. Thus, the higher the value of GRERI for the firm, the higher will be the S–P. Second, the variable BENEX was negatively significant at the 5% level with respect to GREVA, whereby lower BENEX would promote S–P. Third, variable GRERD was negatively significant at the 5% level with respect to GREVA. This may be because, in calculating GRERD, R&D was taken as a proxy for green R&D. Finally, the coefficient for the variable GRETT was positively related to GREVA, but not to a significant degree.[13]

Based on the results from the dynamic panel data framework, we can reject the null hypothesis and accept the alternative hypothesis. Thus, we may conclude that there exists a relation between the S–P of the industry, the S–C of the firm and the S–P of the market in the ISII. As a result, altering the S–P or S–C or both in a specific way will enhance the S–P and *vice versa*.

Our estimates suggest that firms with a higher value of GRERI will have relatively greener performance in the industry. GRERI reveals the relative financial position of the firms within the industry, after taking into consideration its social cost. Firms with a higher value of GRERI are relatively less polluting or comparatively superior in generating higher sales per unit of CO_2 emissions. Those firms exhibit S–S, which may originate from their S–C, which eventually leads to high S–P. Since all the firms belong to the same industry are exposed to similar exogenous conditions, mimicking the S–C of firms with higher GRERI will motivate the firms with lower GRERI and lead them towards S–P in the long run.

Our results also show that the GRERD variable was negatively significant in respect of S–P. Theoretical proposition states that higher significance levels of GRERD are positive correlated with green performance. However, the information about expenditure

[12] Heteroskedasticity arises when the variances of the error terms in the regression model are not constant over different sample observations, $E(e^2) = \sigma_i^2$ (Lee et al., 2013).

[13] Unidirectional specification of the S-SCP paradigm was also tested using the F test and the Hausman test, revealing that a fixed effects panel data model was more efficient and consistent than the alternative random effects panel data model and the pooled model. The results, recalculated using robust standard errors to overcome the inbuilt problem of heteroskedasticity, were similar to those arising from the dynamic analysis, except for the S–C variable; thus, GRETT was positively significant at the 10% level on S–P (GREVA).

on green product manufacturing, eco-processes and eco-solutions were not available for IISI. To overcome this lag, various studies such as Azevedo et al. (2014), Brunnermeier and Cohen (2003) and Jaffe (1997) have used firm's total expenditure in R&D as a proxy of green R&D. They emphasized that although total expenditure in R&D does not immediately imply green R&D, a strong correlation can be assumed. This authenticated us to use the data on R&D as a proxy from green R&D.

The investment in R&D in the IISI is negligible and well below the world standards. Accordingly, low green R&D (around 1%) was undertaking during the 2003–2012 period. Moreover, any R&D investment below the minimum efficient level in a given firm will lead to a proportional higher cost than the benefits derived from the investment. Hence, R&D expenditure will contribute negatively to industry's green performance, which is reflected in our results. Accordingly, there is a need not only for enhancement of R&D practices in the IISI, but also to switch to more environmentally friendly R&D practices in order to enhance the green performance. Once these criteria are met in the IISI, we can expect the GRERD will be positively related to the green performance.

Although India's rank in global innovative index (Cornell University et al., 2018) has improved from 76th (out of 123) in 2012 to 57th in 2018, it still has a comparatively under-developed intellectual property rights system. This hinders the transfer of state-of-the-art green technologies from developed countries. Accordingly, the GRETT coefficient is positive related to GREVA, but not to a significant degree. There is a need for an efficient intellectual property rights system to provide incentives to firms not only to increase R&D investments in green technology, but also to enhance access to CO_2 emission reduction technologies from abroad.

BENEX in the IISI is negatively significant with regard to GREVA. This means that those industries with relatively lower sunk costs will have fewer hurdles so that firms operating there can adopt S–P. For example, industries as manufacturing of electric car require not only shifting to new technologies, but also the coordination with charging infrastructure. Thus, the industries with forward and backward linkages will take a little time to exhibit S–P.

Our study then advocates the establishment of industrial parks to mobilize and manage resources collectively in the interest of using and developing green technologies. Such parks, while spreading sunk cost risk for involved firms, could export state-of-the-art green technologies and earn royalties on green patents.

According to the Central Pollution Control Board (CPCB) of India, the IISI is a red category (i.e. heavily polluting) industry. Firms are obliged to obtain Environmental Impact Assessment (EIA) clearance from the corresponding authority under the EIA notification provisions. The fact that these provisions are silent on the issue of CO_2 emission reductions would suggest a need to incorporate a provision on CO_2 emissions and to provide incentives to project proponents to submit a report on strategies for reduction of CO_2 emissions to obtain the EIA clearance.

Finally, our study also suggests that the Competition Commission of India needs to develop a market and promote competition among firms supplying green products and services. In this case, it would serve as a sustainable development commission to promote competition at the true price (once the social costs are incorporated) of goods and services.

5. Conclusion and future research

Pollution abatement systems such as market-induced correctives and multi-national agreements are *ex-post* in nature and have limited effectiveness in mitigating GHGs, with the resulting costs for humanity and the environment around us. There is a real need for a cost-effective *ex-ante* system that would abate emissions in resource-scarce countries. In this paper, we have described the formulation of a sustainable structure-conduct-performance (S-SCP) model — based on incorporating sustainability in the SCP paradigm — and its application to the Indian iron and steel industry.

Our findings show that the green relative index is positively significant to sustainable performance (S–P), green R&D, and barriers to entry and exit index are negatively significant. The inferences drawn from our analysis allows us to obtain information that could persuade producers to adopt sustainable production practices. As an *ex-ante* system, the proposed model enhances the scope for distributing green profits to shareholders, supplying green products to consumers, improving the quality of life of the population, enhancing preservation of the environment and saving costs for the State. Overall, the S-SCP model may help firms to promote green process (resources harvest-effort at profit maximization/maximum sustainable yield, recycle), products (intermediary and final), services (financial, patents, technology) and policies (efficient-double dividend/representative responsibility) for society's sustainable gross domestic product.

Concerning the limitations and future extension of this work, the unavailability of information on renewable inputs, namely scrap steel and percentage share of renewable energy, made it difficult to calculate the REIDX and GREFM values. As result, these two S–S variables were dropped from the empirical analysis. Analogously, data on GREAD was unavailable, and, accordingly, this S-C variable was also dropped from the analysis. The absence of these variables may affect the outcome of the study. In addition, the research only undertook CO_2 as the greenhouse gas for the analysis. However, there are other GHGs as well that can also be considered. In this respect, we plan in the future to develop and define variables that capture social performance directly in the S-SCP paradigm. We also plan to formulate a survey based on structured questionnaire and interviews with firms' managers to collect their opinions on adaptation to sustainable production practices and will apply the S-SCP model to energy-intensive industries both at the national and international level.

Paris Agreement 2015 highlights the role of non-state players is as important as the role of the state in mitigating CO_2 emissions. Accordingly, non-state players *viz*., Maersk, VMware, Google, Microsoft, Apple, Adobe, Allianz, United Postal Services (UPS) have committed to carbon neutrality. Similarly, the Energy Transitions Commission's report on "Mission Possible 2018" (ETA, 2018) states that it is possible for sectors *viz*., cement, steel, plastics, shipping, trucking and aviation to become net carbon neutral by 2050 by the adoption of S-C. Therefore, application of the S-SCP paradigm to various sectors across the nations will help in accelerating the global energy conservation.

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